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PRECOOKED DEHYDRATED SWEETPOTATO FLAKES

U. S. DEPARTMENT OF AGRICULTURE
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This is a report of work done in the

SOUTHERN REGIONAL RESEARCH LABORATORY
Southern Utilization Research and Development Division
Agricultural Research Service

and in the

QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES
Quartermaster Research and Engineering Command
Department of the Army

PRECOOKED DEHYDRATED SWEETPOTATO FLAKES

by

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ABSTRACT

Precooked dehydrated sweetpotato flakes. I. A method for processing. Processing steps are reviewed for the small-scale preparation of experimental batches of precooked dehydrated sweetpotato flakes from cured Goldrush and Unit I Porto Rico varieties. The steps involve washing, preheating, peeling, slicing, cooking, pureeing with addition of water to roughly 20% solids, incorporation of sulfites and antioxidant in the puree, dehydrating the puree on a double drum drier, and packaging of the flake product in an atmosphere of nitrogen. **II. Selected processing variables and their effects on flake characteristics.** Experimental data are presented for 16 batches of sweetpotato flake products prepared from Goldrush and Unit I Porto Rico varieties during the 1958-59 processing season. Variables involved were: (1) pressure cooking at 240° F. for 18 minutes, and atmospheric steam cooking at 212° F. for 25 to 30 minutes, (2) Goldrush and Unit I Porto Rico variety sweetpotatoes as raw materials, (3) processing at two storage intervals after curing, and (4) preparation of flakes with and without antioxidant. The flakes, ranging in moisture content from 3.2% to 5.6% (average 4%) and packed in nitrogen in sealed tin cans were stored at 70° and 100° F. Good product stability was obtained in the batches of flakes prepared with antioxidant (0.1% Tenox VI [5] dry solids basis), and in the individual samples of these same batches in which the oxygen content of the atmosphere in the sealed container was less than 2%. These two conditions were the major ones determining the stability characteristics of the experimental products. When these two conditions were met, carotene, ascorbic acid and flavor retention were higher than when the conditions were not met. The investigations demonstrated that good quality flakes could be made by both methods of cooking, from both varieties of sweetpotatoes tested, and from sweetpotatoes cured and stored for more than 90 days. They further demonstrated that the flakes containing antioxidant and sealed in an atmosphere low in oxygen could be safely stored at 70° and 100° for over a year. Although satisfactory methods of producing experimental products of good quality and stability have been demonstrated, evidence has also been provided which shows the need for further developmental work. **III. Preference evaluation.** Data presented denote the relative effects of the experimental variables on consumer preference over a 12-month period. Possible interpretations of various 2- and 3-factor interactions are also discussed. Material representing each of the 16 experimental batches discussed in Section II were placed in 70° and 100° F. storages at the Quartermaster Food and Container Institute for the Armed Forces. Flakes were withdrawn periodically from storage, and the reconstituted product was evaluated by groups of consumers using the hedonic scale method, which has a 9-point rating scale with verbal anchors expressing successive degrees from "dislike extremely" to "like extremely." The product was served as mashed sweetpotatoes. Results of study indicated that length of prestorage of cured roots and variety had, in general, no

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[5] Mention of trade products does not imply indorsement of them by the U. S. Department of Agriculture, or the Department of the Army, over similar products not mentioned.

effect on preference. Further, while there was a general loss of preference over time, the preference for samples stored at 100° F. declined at a less rapid rate than for samples stored at 70° F. Preference ratings for sweetpotatoes cooked in atmospheric steam were slightly but significantly higher than for those cooked under pressure. Improvement of product stability by the addition of an antioxidant was indicated. A low oxygen residual in the sealed container appeared to be needed for good stability. The results of these evaluation tests may be contrasted with the evaluations described in Section II. The latter were made by a small panel of technologists who were familiar with the products they were evaluating. In contrast, this study encompasses 2,880 judgments made by 720 "typical" consumers having no particular concepts or biases about the product.

I. A METHOD FOR PROCESSING

The processing steps and procedures outlined below are those which have been found successful in the small-scale manufacture of a precooked dehydrated sweetpotato flake product. The flake product, which is in the experimental stage, has been made within a relatively wide range of processing conditions. Some of these are described in Section II of this report. The procedures outlined are based upon: (1) Modifications of those developed by the Eastern Utilization Research and Development Division for the manufacture of white potato flakes, (2) those in use in the sweetpotato canning industry, and (3) those recommended in the literature and supported by additional experimental evidence.

It is emphasized that these procedures are not necessarily, as given, the ones that will be ultimately recommended or found adequate for commercial practice. Collectively, however, they comprise a method for making a flake product which has remained stable for well over a year at a temperature of either 70° or 100° F. They form a background for work toward the development of a consumer acceptable product which may be produced on a large scale. [6]

Raw Materials

The results given in this report were obtained with cured sweetpotatoes of the Goldrush and Unit I Porto Rico varieties. Both varieties were processed within 5 to 150 days after curing. No particular specification has been found necessary as to sizes and shape. All sound sweetpotatoes, free from spoilage when peeled and trimmed, proved satisfactory for processing.

Washing

Conventional methods for cold water washing, through the use of standard sweetpotato canning plant equipment, are satisfactory in preparing the raw roots.

Preheating

In the experimental work, washed sweetpotatoes are placed in a wire mesh basket and immersed in water at 160° F. for 30 minutes preparatory to lye peeling. Variations in combinations of time and temperature of preheating can undoubtedly be made in commercial operation. The treatment is currently recommended in that it reduces discoloration, aids in peeling because of the increase in temperature of the outer layers, and may aid in increasing the sugar content of the finished product.

Peeling and Trimming

The objective of this processing step is to remove the peel and unwanted parts of the sweetpotato, with a minimum loss of edible portions and to reduce as much as possible the labor cost involved in the trimming. In the experimental work, the pre-heated roots are transferred immediately to a rotary lye peeler and submerged in 20 to 22% sodium hydroxide solution at 220° F. for 6 minutes. The loosened peel and lye are washed away in a squirred cage (rotary) washer by strong jets of cold water. The roots are then hand trimmed and cut lengthwise so that the maximum thickness is not more than 1-¼ inches.

[6] A pilot plant capable of producing about 40 pounds of flakes per hour has recently been installed at the Southern Regional Research Laboratory, New Orleans, Louisiana. This new plant will be used to obtain cost, yield, and engineering data, translatable to commercial production; also to develop improved processing procedures.

Cooking

Cooking is one of the more critical of the processing steps in achieving high quality characteristics in the finished product. Undercooking or overcooking has resulted in "poor" flavor. A blanching procedure has given good results in the small-scale production of flakes. The cut and trimmed sweetpotatoes are placed on a wire mesh stainless steel tray at 3 to 3.5 pounds per square foot. The tray in turn is placed in the blancher where the sweetpotatoes are cooked in steam at atmospheric pressure at 212° F. for 25 to 30 minutes—the time depending on the characteristics of the particular lot of sweetpotatoes being processed. Preliminary experiments have shown that any delay from the preheating step through the cooking step is detrimental to product stability. Considerable loss of solubles in the condensate, as a leaching out is inherent in this cooking method. It is obvious that further work on cooking in water and in sirup, and on related methods, is required to determine the optimum cooking procedure. Maximum yield and production efficiency in commercial operation will depend largely on the development of cooking procedures.

Pureeing

In small-scale processing it has been observed that a 20% solids content puree may be easily fed to and readily adheres to the drum drier rolls to produce a flake of good physical characteristics. The dilution to a 20% solids content is accomplished by the addition of hot water to the cooked potatoes. Sodium sulfite and sodium bisulfite (0.06 g. sodium sulfite and 0.02 g. of sodium bisulfite per pound of 20% solids puree) are added to the water used for dilution. An antioxidant, Tenox VI,[5 7] at a level of 0.1% of the dry solids in the puree is also added to the dilution water in the form of an emulsion. This mixture (cooked sweetpotato, water, antioxidant, and sulfites) may be pureed in a suitable pulping machine—in a Hobart mixer [5] with a whipping attachment, or in any commercial pulper. The Langsenkamp Indiana pulper (finisher) [5] has been used in the more recent laboratory experiments. Pureeing is done rapidly without undue loss of heat from the mash. The hot puree is dried promptly to avoid discoloration and other undesirable chemical changes.

Drying

If the puree is properly diluted to the desired consistency for drum drying, the drying step is comparatively simple. The double drum drier used for the small-scale experimental flake production has rolls 12 by 18 inches. These rolls are heated with steam under 75 pounds' pressure; they are set at 0.010-inch clearance at working temperature and driven at approximately 2 r.p.m. It was found necessary to agitate the puree as it was being fed into the "trough" between the rolls, to insure an even distribution of the material between and along the rolls. About 17 seconds is required of actual contact of the material on the rolls for the doctor blade to release a dried sheet. While the operation is simple and direct in principle, good operating technique is essential. The level of the puree between the rolls must remain constant, and the machine must be under surveillance at all times so that a uniform sheet of dried cooked sweetpotatoes is steadily emerging. The dry sheet is usually between yellow and orange in color and has a crinkled appearance. The sheet product should be uniform in thickness and texture and contain 3 to 5% moisture. It is somewhat plastic for a few seconds, after which time it becomes brittle and capable of being mechanically broken into irregular flake size pieces. It needs to be protected from humid atmospheres since it is slightly hygroscopic. With the equipment and procedure used, the yield of dry product was 12 to 15 pounds per hour.

Packaging

The flakes require special handling in order to stabilize the flavor. When exposed to air for 24 hours or longer they develop an undesirable haylike flavor and odor. They must, therefore, be hermetically sealed in an atmosphere of nitrogen containing less than 2% oxygen. When the product is sealed in air, the antioxidant does not furnish sufficient protection against flavor deterioration on long storage.

Precooked dehydrated sweetpotato flakes made and packaged in accordance with the above procedures have remained stable for

[7] Tenox VI, manufactured by Eastman Chemical Products, Inc., Kingsport, Tennessee, contains butylated hydroxyanisole (10%), butylated hydroxytoluene (10%), propyl gallate (6%), citric acid (6%), propylene glycol (12%) and vegetable oil (56%).

test periods of over a year. They reconstitute readily, almost instantly, when mixed with hot water, milk, or other liquid in proper proportions (a water/flakes ration of 3/1 was found satisfactory for the products of these experiments). The resulting dehydrated puree or mashed sweetpotato has the flavor and other acceptance characteristics of puree made from freshly cooked sweetpotatoes.

The major problem encountered in the experimental work to date is that of product stabilization—the prevention of off-flavor and off-odor development. Improvements in the mechanics of processing should aid in the solution of this problem. Careful control throughout processing is essential. It is probably necessary to package the experimental flakes in hermetically sealed packages with the antioxidant in an inert atmosphere to insure adequate stability. The antioxidant used for this product does not yet have approval from the Food and Drug Administration, U. S. Department of Health, Education, and Welfare, nor has the need for antioxidant been completely established. Vacuum packing was not among the variables tested.

II. SELECTED PROCESSING VARIABLES AND THEIR EFFECTS ON FLAKE CHARACTERISTICS

INTRODUCTION

Interest in the possibility of a precooked dehydrated sweetpotato flake product reached the action stage in Louisiana in 1956. White potato granules already were a successful convenience item in the retail markets of the Nation. White potato flakes had been successfully developed and were gaining the attention of commercial processors of potato products. There were no comparable sweetpotato products. An "instant" flake product was considered ideal for inclusion in quick-serve meals, for institutional and home use, and for military field rations. Canned sweetpotatoes were the only processed sweetpotato product of any significance. Small quantities of sweetpotatoes were being frozen for food markets, and some were going into dehydrated feeds.

Members of the southern sweetpotato industry believed that a precooked dehydrated sweetpotato product might increase the use of sweetpotatoes and that it would also provide a more profitable market for the edible odd-sized and odd-shaped sweetpotatoes that may make up 30 to 50% of the crop and run even higher in some years. The quantity of edible sweetpotatoes not meeting the premium fresh market grade requirements as to size and shape is far in excess of canning needs. They frequently do not yield profitable returns to the grower; when they reach the fresh market they may even depress the price for the premium grade.

The Quartermasted Food and Container Institute for the Armed Forces (QMF&CI) expressed a positive interest in a precooked dehydrated sweetpotato flake product about the same time as industry.

With this background the Southern Utilization Research and Development Division (SURDD) in the 1956-57 and 1957-58 seasons began a series of investigations in cooperation with the QMF&CI and the Department of Horticulture, Louisiana State University (LSU), to develop a precooked dehydrated sweetpotato flake product. A product was desired which would have a long shelf-life, which would readily rehydrate, and which on reconstitution would resemble in flavor and other characteristics the freshly cooked puree made from raw sweetpotatoes of good quality. These early unpublished investigations were preliminary in nature. They did demonstrate, however, that the problems in the mechanics of producing flakes were surmountable, and they did produce leads for the stabilization of flakes. In designing and conducting the investigations full use was made of the information published and/or released by the Eastern Utilization Research and Development Division (8, 9, 10, 11, 12, 14, 17, 32) [8] on the processing of white potato flakes, and of our own first-hand knowledge of processing steps in common use in the canning of sweetpotatoes in Louisiana, and in the small pilot-scale production of raw dehydrated dice (2, 3, 4, 5).

Historically, interest in the development of precooked dehydrated sweetpotato products

[8] Numbers in parentheses refer to Literature Cited at end of this Section.

originated over 40 years ago. Mangels and Prescott (23) endeavored to manufacture a sweetpotato flour by the "flake process, but they were not successful in obtaining a satisfactory product. The resulting flour was hygroscopic, frequently greenish, and on storage hardened and developed a strong odor.

In contrast, Ware, Harris, and Johnson (19, 20, 21, 30, 31) prepared several dried cooked sweetpotato (Alayam) products of excellent quality. In the preparation of the Alayam products—flour, snacks, breakfast cereals, and the like—the sweetpotatoes passed through a series of cooking and drying steps. The drying was not done on a drum drier, however, a basic difference distinguishing their product preparation from that of Mangels and Prescott (23) and that of the authors of this paper.

All work on the development of a precooked dehydrated sweetpotato flake product at the SURDD has involved the use of the double drum drier. The purpose of this second section is to describe the experimental work undertaken and the results obtained during the 1958-59 processing season. During this season, experiments were planned to test the optimum processing conditions established during the previous season (unpublished data) and to produce an acceptable product in larger quantities on a semi-pilot-plant scale for a more complete chemical and sensory evaluation by SURDD and QMF&CI personnel. In addition, it was desirable to determine the value of an antioxidant and the influence of storage of the raw cured roots for 100 days and over, on the quality characteristics of the flakes. Sixteen experimental batches of flakes were prepared for the purpose of testing the effects of the following treatments on flake quality characteristics; (1) Two methods of cooking (steam blanching ata 212° F. for 25 to 30 minutes; and pressure cooking at 240° F. for 18 minutes); (2) two varieties of sweetpotatoes (Unit I Porto Rico and Goldrush); (3) two intervals of storage of the raw cured roots; and (4) absence or presence of an antioxidant.

RAW MATERIALS

Both Goldrush and Unit I Porto Rico varieties of sweetpotatoes were grown on the same farm near St. Francisville, Louisiana. A sufficiently large lot of each variety was purchased to process all the experimental batches required. The Goldrush sweetpotatoes were dug and stored in the curing shed on September 1, 1958, then on September 15, shipped to the Southern Regional Research Laboratory, New Orleans. The Unit I Porto Rico's were dug and stored in the curing shed October 28, 1958, then shipped November 14. The roots of the latter variety were not as good a quality as are available in most seasons. They were lacking in uniformity of color, and in uniformity of size and shape normally characteristic of the crop. Both lots of sweetpotatoes were stored immediately on their delivery at the Southern Regional Research Laboratory at a temperature of 60° to 62° F. and held until processed.

METHODS

Processing Procedures

In general, processing was accomplished in the following manner: The washed sweetpotatoes were preheated in hot water at 160° for 30 minutes (24, 25, 27). They were then peeled in a lye peeler by immersing for 6 minutes in a 20 to 22% caustic bath at 220°, followed by spraying with strong jets of cold water in a rotary washer to remove the loosened peel. Fibrous ends, scar tissue, and other discolored adhering material were removed by hand trimming. The sweetpotatoes were cut into strips or larger pieces (slices not exceeding 1-¼ inches in thickness).

Atmospheric steam cooking at 212° F. was accomplished by placing the sliced sweetpotatoes on a stainless-steel wire mesh tray in a steam blancher. In pressure cooking the sweetpotatoes were placed in a woven wire basket suspended in a canning retort.

Pureeing was done in a Hobart [5] mixer, after sufficient water was added to give a puree of 20% solids content. A small amount of sodium sulfite and of sodium bisulfite (0.06 g. and 0.02 g. per pound of 20% solids puree) was added to the dilution water. With these sweetpotatoes it was not necessary to remove fibrous material from the puree to obtain a uniform-textured final dehydrated product. The puree was transferred to the hopper feeding the double drum drier as rapidly as possible.

Two or three 75-pound lots of raw sweetpotatoes (150 or 225 pounds) were processed for each set of variables, usually three lots, in which case two were processed on one day and the third on the following day.

Processing procedures through the cooking step were accomplished with minimum delay. Because the blanching equipment was small, it was necessary to divide each 75-pound lot of sweetpotatoes into three 25-pound portions. The processing of each of the 25-pound portions was staggered in such a manner that the blancher would be free to cook each succeeding portion immediately after peeling and trimming was completed. The 25-pound portions of cooked sweetpotatoes were separately pureed and held in a hot water bath (140° F.) until the entire 75-pound lot had been processed. The three pureed batches were mixed together; the mixture was adjusted to 20% solids by the addition of hot water, then drum dried.

When Tenox VI [3] antioxidant was added to the dilution water as a variable, the amount required (0.1% of the dry solids in the puree) was first emulsified in the hot water to be used to adjust the puree solids. This emulsion was then mixed into the original puree. In the drying process the drum drier was adjusted according to the conditions worked out in the preliminary experiments: Drying time (product in contact with the drum surface) 17 seconds; steam pressure to the drums 75 p.s.i.; and drum clearance (at operating temperature) 0.010 inch.

As the sheet of dry product was removed from the rolls it was broken and collected in 30-pound tins. In the event, that three 75-pound lots of sweetpotatoes were processed, the flakes from the first day's two runs were sealed in a large container under nitrogen. When the second day's single run was completed, the flakes were composited and sealed under nitrogen, in No. 303 tin cans, 150 g. per can. The small, irregular sized flakes were produced by passing the sheetlike material from the drier through a modified Mills coconut grater. [5]

Table 1.—Dates, codes, and conditions of processing 16 batches of precooked dehydrated sweetpotato flakes, 1958-59 season [1]

Date of processing	Sample code No.	Steam Pressure		Atmos. Steam		Tenox VI	Moisture content of flakes (%)
		temp. (°F.)	time (min.)	temp. (°F.)	time (min.)		
		Goldrush (Cured; 50 to 58 Days' Storage)					
11/4-5	F42-8	240	18	—	—	None	4.0
11/6-7	F42-9	240	18	—	—	0.1% [2]	3.5
11/10-11	F43-1	—	—	212	25	None	3.5
11/12-13	F43-2	—	—	212	25	0.1% [2]	3.6
		Unit I Porto Rico (Cured; 5 to 20 Days' Storage)					
11/19-20	F43-4	240	18	—	—	0.1% [2]	4.9
11/24-25	F43-5	—	—	212	25	0.1% [2]	5.1
12/1-2	F43-6	—	—	212	25	None	5.6
12/4-5	F43-7	240	18	—	—	None	4.0
		Goldrush (Cured; 141 to 150 Days' Storage)					
2/3	F44-7	240	18	—	—	None	4.2
2/4	F44-8	240	18	—	—	0.1% [2]	3.3
2/9-11	F44-9	—		212	25	None	4.0
2/12-13	F45-1	—	—	212	25	0.1% [2]	4.1
		Unit I Porto Rico (Cured; 102 to 110 Days' Storage)					
2/24	F45-2	240	18	—	—	None	4.0
2/25	F45-3	—	—	212	25	None	3.9
3/2-3	F45-4	240	18	—	—	0.1% [2]	3.2
3/4	F45-5	—	—	212	25	0.1% [2]	3.3

[1] All processing conditions held constant except for variables shown.
[2] Dry-solids basis.

Experimental Variables and Packs

The combinations of experimental variables investigated, dates of processing, and code numbers of the packs are given in Table 1. The first eight experimental batches of flakes were prepared during the period November 4 to December 5, 1958; all were processed in the same manner, except as indicated in Table 1. They were made from raw materials within 5 to 58 days of curing. A second series was made after the cured sweetpotatoes had been stored for 102 to 150 days.

Approximately 8 pounds of flakes from each of the 16 different experimental batches (24 cans of 150 g. per can) was shipped to the QMF&CI laboratories, Chicago, Ill., for acceptance testing. The remaining cans of product from each batch were equally divided and stored at 70° and 100° F. at the Southern Regional Research Laboratory. The stored samples were checked for flavor at weekly intervals for 3 months and at 2-week intervals thereafter. Both flakes and raw sweetpotatoes were analyzed for carotene, ascorbic acid, total sugars, reducing sugars, and moisture at intervals during the processing and storage periods.

Chemical and Sensory Methods

Moisture was determined by the procedure recommended in the AOAC "Official Methods of Analysis" for determining moisture in dried fruits (6). The quantities of products used were 5 to 6 g. of ground (Waring Blendor[5]) raw sweetpotato, 5 to 6 g. of pureed cooked sweetpotatoes, and 2 g. of the sweetpotato flakes.

β-Carotene was also determined by an AOAC method (6). The several steps involved in the preparation of the extract for analysis from raw sweetpotatoe were as follows: Five grams of the ground raw material (Waring Blendor)[5] were transferred to a Waring Blendor[5] cup. One hundred milliliters of ethanol were added and the mixture blended at high speed for 5 minutes. The blended mixture was transferred to a 500-ml. Erlenmeyer flask. The transfer was completed by washing the cup several times with small quantities of 40:60 mixture of petroleum ether (Skelly F[5]) and ethanol. After the mixture in the flash was stirred, the residue was allowed to settle. The clear supernatant liquid was decanted into a 500 ml. separatory funnel. The residue in the flask was washed successively with 25 to 30 ml. portions of the petroleum ether-ethanol mixture until all the color was gone—and finally three times with 25 to 30 ml. portions of petroleum ether. All washings were decanted into the separatory funnel and 10 to 20 ml. of water was added to bring about a sharper separation of the pigment layer. The water-ethanol layer was then removed and the petroleum ether layer washed six to seven times with 100 ml. quantities of water. The petroleum ether containing the carotene was then drawn through the petroleum-ether-saturated dibasic calcium phosphate-celitc column overlayed with a small quantity of anhydrous sodium sulfate; then the column was washed with petroleum ether. This chromatographic column is about 9 cm. in length and 2.2 cm. in diameter. As the carotene passes through the column, other pigments are adsorbed on the column. The collected eluate is transferred to a 250 ml. volumetric flask and made up to volumn. The optical density of the solution is determined with a spectrophotometer at 436 mμ. The density is converted to concentration and the concentration is reported as parts per million of β-carotene on a dry solids basis.

β-Carotene concentration of precooked dehydrated sweetpotato flakes is determined in the same manner. In this case, however, only 1 gram of material is used. The flakes are not reground but are transferred directly to the Erlenmeyer flasks, moistened, with 5 to 6 ml. water and the procedure followed through from this stage as for the raw material.

Ascorbic acid was determined by a visual titration method—the reduction of 2,6-dichlorophenolindophenol by an acid solution of ascorbic acid (7). In the preparation of the raw sweetpotato for analysis, 150 g. of ground material was blended 3 to 5 minutes in a Waring Blendor[5] cup with 150 g. of 6% metaphosphoric acid. A 30-g. portion of the homogeneous slurry was quantitatively transferred to a 100 ml. volumetric flask and made up to volume with 3% metaphosphoric acid. The suspended material was removed by centrifugation. An aliquot (10 ml.) of the clarified solution was titrated with 0.025% 2,6-dichlorophenolindophenol solution to a pink end point which persisted for 15 seconds. The dye solution was standardized by titrating against a freshly prepared ascorbic acid standard each day it was used. Ascorbic acid content was reported as milligrams per 100 g. of sweetpotato, dry basis.

Ascorbic acid content of flakes was determined in the same manner except only 5 g. of the sample was used in each analysis. The 5 g. was transferred quantitatively to a volumetric flask. Seventy-five grams of 3% metaphosphoric acid was added and the mixture steeped at room temperature with occasional shaking for 1 hour. Twenty milliliters of acetone was added to eliminate the effect of the residual sulfite remaining in the flakes from the processing treatment. The mixture in the volumetric flask was made up to volume, and the procedure followed through from this stage as for the raw material.

Reducing and total sugars were determined by the Munson-Walker general method for sugars (6). The extract was titrated with a standardized potassium permanganate solution by use of a ferrous phenanthroline indicator. In the preparation of the sweetpotato extract 5 g. of raw ground sweetpotatoes or of precooked dehydrated flakes was transferred to a volumetric flask. One hundred and fifty to 200 ml. of 80% ethanol was added. After thorough agitation, the mixture was heated (boiled) for 1 hour on a steam bath, cooled, made up to volume with 80% ethanol, and filtered through dry fluted filter paper into an Erlenmeyer flask and the procedure continued.

Taste testing of the rehydrated flakes was reduced to a simplified procedure. Three to six people who have had extensive experience in tasting sweetpotato products were used. The criterion was simply whether the individual taster considered the sample good (acceptable) or not good to his palate. Comparative evaluation between samples was not attempted because of the small number of people readily available for sensory evaluation work. A trained panel was not considered essential at this stage of the experimental work.

Methods and results concerning consumer preference evaluation studies made by QMF&CI personnel on corresponding samples from the same 16 experimental batches of flakes are described in Section III.

RESULTS

The data obtained in the preparation of the 16 batches of experimental precooked dehydrated sweetpotato flake products are given in Tables 2 to 7, inclusive.

At intervals throughout the storage period analyses were run on samples of raw sweet-

Table 2.—Moisture, β-carotene, ascorbic acid, and reducing and total sugars in raw cured sweetpotatoes used in experiments.

Date of examination (1958-59)	Time in storage (days)	Moisture (%)	β-Carotene [1] (p.p.m.)	Ascorbic acid [1] (mg./100 g.)	Sugars [1]	
					Red. [2] (%)	Total (%)
			Goldrush			
10/7	22	75.1	454	80	—	—
10/23	38	74.6	460	86	5.7	26.2
10/28	43	75.7	460	84	7.0	22.8
11/4	50	74.8	417	86	5.1	24.3
11/10	56	76.6	404	77	6.5	27.9
2/2	140	76.1	431	85	7.7	30.8
2/9	147	77.7	509	83	10.3	35.7
3/17	182	79.7	534	96	—	—
3/31	197	80.8	450	93	—	—
			Unit I Porto Rico			
11/18	4	68.3	112	76	2.5	12.7
11/26	12	68.5	178	92	2.8	14.8
12/2	18	68.8	74	92	1.5	11.5
12/7	23	68.2	—	91	1.6	11.8
2/27	105	69.0	186	78	4.4	19.4
3/8	114	69.1	113	74	3.6	17.3

[1] Dry basis.
[2] Reducing sugars.

potatoes to determine whether there are appreciable changes in the moisture content, β-carotene, ascorbic acid, and reducing and total sugars. The results of the chemical determinations are given in Table 2. Sugars tended to increase with the storage period but marked changes in the other constituents measured were less in evidence. This study was not intended, however, as a study of storage effects. The intention, rather, was to learn whether there were any great differences in the quality of the raw materials being processed throughout the season, particularly with respect to the constituents measured. Storage effects per se have been extensively reported in the literature (1, 13, 15, 16, 18, 22, 26, 28, 29).

The moisture content of the flakes at the time of processing are shown in Table 1. These ranged for the 16 batches from 3.2 to 5.6% with an average of 4%. Moisture determinations were made at different intervals during the storage both at the 70° and 100° F. temperatures. There were variations, but no marked quantitative departures or trends from the initial moisture contents that are not explainable as possibly the results of sampling errors and differences in individual samples (cans) from the same batch of flakes.

Carotene values, reported as β-carotene, were quite variable; in addition the values for the stored flakes averaged only slightly lower than those for the freshly prepared flakes (Tables 3 and 4). Because of the wide variability, only average values are given for the determinations made during each 3 months' storage period. To illustrate the variability in the case of run

Table 3.—Data on carotene, ascorbic acid, and flavor acceptability of precooked dehydrated sweetpotato flakes stored at 70° and 100° F.—raw materials processed within 5 to 58 days after curing [1]

Run No.	Processing [2] code	β-Carotene [3] (p.p.m.)				Ascorbic acid [3] (mg./100 g.)				Storage acceptability of flakes (days)
		Initial	1-3 mo.	4-6 mo.	7-9 mo.	Initial	1-3 mo.	4-6 mo.	7-9 mo.	
				Goldrush Flakes Stored at 70° F.						
F42-8	P—	568	526	500	533	85	75	75	—	114 [4]
F42-9	P+	566	559	557	534	85	83	80	75	327 [5]
F43-1	A—	500	489	468	459	94	87	81	—	164 [4]
F43-2	A+	503	518	484	486	92	83	80	76	321 [5]
				Goldrush Flakes Stored at 100° F.						
F42-8	P—		519	508	417		75	—	—	114 [4]
F42-9	P+		542	524	420		79	65	48	327 [5]
F43-1	A—		488	463	415		81	69	—	293 [4]
F43-2	A+		511	478	465		84	75	59	321 [5]
				Unit I Porto Rico Flakes Stored at 70° F.						
F43-4	P+	172	159	161	140	77	78	73	66	314 [5]
F43-5	A+	165	141	147	142	85	79	73	68	309 [5]
F43-6	A—	141	138	135	—	82	78	71	—	60 [4]
F43-7	P—	204	194	186	—	81	80	79	—	57 [4]
				Unit I Porto Rico Flakes Stored at 100° F.						
F43-4	P+		155	149	128		74	57	40	314 [5]
F43-5	A+		143	128	106		77	58	31	309 [5]
F43-6	A—		125	121	—		73	61	—	60 [4]
F43-7	P—		206	180	—		77	75	—	57 [4]

[1] Chemical analysis reported on dry solids basis.
[2] A = atmospheric cook; P = pressure cook; — = without Tenox VI; + = 0.1% Tenox VI (dry basis).
[3] Determination made on freshly processed and canned flakes. Averages of determinations during 1st, 2d, and 3d storage periods.
[4] Samples developed off flavor at storage time indicated.
[5] Acceptable flavor.

Table 4.—Data on carotene, ascorbic acid and flavor acceptability of precooked dehydrated sweetpotato flakes stored at 70° and 100° F.—raw materials processed within 102 to 150 days after curing [1]

Run No.	Processing [2] code	β-Carotene [3] (p.p.m.) Initial	1-3 mo.	4-6 mo.	Ascorbic acid [3] (mg./100 g.) Initial	1-3 mo.	4-6 mo.	Storage acceptability of flakes (days)
		Goldrush Flakes Stored at 70° F.						
F44-7	P—	673	587	573	65	71	—	65 [4]
F44-8	P+	666	615	536	62	73	66	238 [5]
F44-9	A—	564	528	508	72	66	—	75 [4]
F45-1	A+	505	551	501	65	61	60	229 [5]
		Goldrush Flakes Stored at 100° F.						
F44-7	P—		561	542		64	—	65 [4]
F44-8	P+		630	513		64	60	238 [5]
F44-9	A—		500	458		60	—	88 [4]
F45-1	A+		529	404		53	42	229 [5]
		Unit I Porto Rico Flakes Stored at 70° F.						
F45-2	P—	172	190	177	75	69	—	45 [4]
F45-3	A—	155	156	153	69	68	—	95 [4]
F45-4	P+	207	210	195	77	71	71	209 [5]
F45-5	A+	168	172	148	73	67	67	208 [5]
		Unit I Porto Rico Flakes Stored at 100° F.						
F45-2	P—		188	162		67	—	163 [4]
F45-3	A—		153	160		67	59	162 [4]
F45-4	P+		210	174		70	66	209 [5]
F45-5	A+		169	154		66	61	208 [5]

[1] Chemical analysis reported on dry solids basis.
[2] A = atmospheric cook; P = pressure cook; — = without Tenox VI; + = 0.1% Tenox VI (dry basis).
[3] Determination made on freshly processed and canned flakes. Averages of determinations during 1st and 2d storage periods.
[4] Samples developed off flavor at storage time indicated.
[5] Acceptable flavor.

number F43-2 (Goldrush), the β-carotene value for the freshly prepared flakes was 503 p.p.m. whereas in the individual samples stored at 70° F. the range was from 447 to 582 p.p.m. with a sample as high as 520 p.p.m. at the end of the 9-month period. Similarly for run number F42-9, 566 p.p.m. were recorded for fresh flakes, with a range from 427 to 632 p.p.m. for individual samples stored at 70° F. and with a sample as high as 541 p.p.m. at the end of the 9-month period. These ranges in values were typical for individual samples of freshly made and stored Goldrush flakes. Carotene values for samples of flakes made from Unit I Porto Rico varied in the same manner. However, there is an indication of a trend for the carotene values to decrease with length of storage and to decrease to a greater extent at 100° than at 70°. This observation, however, needs confirmation.

The ascorbic acid values of stored flakes were fairly constant. In general the destruction was greater and more rapid at 100° F. than at 70° F. (Rates of ascorbic acid decrease did not appear, however, to correlate with those of flavor deterioration. See footnotes 4 and 5 of Tables 3 and 4.)

Total and reducing sugars are not reported in the tables. Determinations for the whole storage period of the flakes at 70° and 100° F. were not made because the values that were determined did not show trends; differences were no greater than might be anticipated from the sampling and processing variables. It is interesting to note, however, that total and reducing sugars are slightly higher in those

batches of flakes processed from the older sweetpotatoes. The magnitude of this difference is illustrated by the following tabulation:

Flakes made from sweetpotatoes stored (days)	Total sugars (%)	Reducing sugars (%)
Goldrush		
50 to 58	38.3	20.1
141 to 150	45.6	21.3
Unit I Porto Rico		
5 to 20	38.6	23.5
102 to 110	40.4	26.5

Information on the storage acceptability, or shelf life, of the 16 experimental flake products is given in days in the right-hand column in Tables 3 and 4. All samples without antioxidant had a much shorter storage life (as determined by length of time of flavor acceptability). While no consistant differences in the stability of the flakes made from Goldrush and Unit I Porto Rico were apparent, those processed from the Unit I Porto Rico without antioxidant usually developed an off-flavor before corresponding samples produced from Goldrush. Storage of the raw sweetpotatoes at 60° to 62° for over 100 days before processing did not seem to influence the keeping quality of the flakes prepared from them within the storage time the flakes were evaluated. The two cooking conditions investigated generally gave similar results when an antioxidant was incorporated in the flakes. Without antioxidant, however, the atmospherically cooked product was usually somewhat more stable than the corresponding pressure cooked one.

Erratic results with respect to carotene and ascorbic acid contents and particularly to flavor were observed in testing samples of the 16

Table 5.—Data on carotene, ascorbic acid, and flavor acceptability of precooked dehydrated sweetpotato flakes stored at 70° and 100° F.—data obtained on canned samples containing less than 6% oxygen in the gas [1]

Run No.	Processing [2] code	β-Carotene (p.p.m.)		Ascorbic acid (mg./100 g.)		Flavor acceptability		Days storage to date
		70°	100°	70°	100°	70°	100°	
Goldrush Processed Within 50 to 58 Days Raw Storage								
F42-8	P—	533	571	—	—	—	good	329 [4]
F42-9	P+	531	—	78	50	fair	—	327 [4]
F43-1	A—	478	472	83	57	good	good	323 [4]
F43-2	A+	511	492	79	61	good	good	321 [4]
Unit I Porto Rico Processed within 5 to 20 Days' Raw Storage								
F43-4	P+	146	140	69	42	good	good	314 [4]
F43-5	A+	126	120	71	32	good	good	309 [4]
F43-6	A—	135	126	—	64	off	off	— [3]
F43-7	P—	186	179	79	74	off	off	— [3]
Goldrush Processed Within 141 to 150 Days' Raw Storage								
F44-7	P—	565	558	68	49	good	good	239 [4]
F44-8	P+	548	565	68	61	good	good	238 [4]
F44-9	A—	551	525	70	54	good	good	231 [4]
F45-1	A+	517	472	59	48	good	good	229 [4]
Unit I Porto Rico Processed Within 102 to 110 Days' Raw Storage								
F45-2	P—	193	166	70	62	off	off	— [3]
F45-3	A—	199	—	69	56	off	off	— [3]
F45-4	P+	175	199	75	66	good	good	209 [4]
F45-5	A+	153	159	68	62	good	good	208 [4]

[1] Chemical analyses reported on dry solids basis.
[2] A = atmospheric cook; P = pressure cook; — = without Tenox VI; and + = 0.1% Tenox VI (dry basis).
[3] These samples were off-flavor when samples stored in low oxygen were tested in September 1959.
[4] Acceptable flavor when samples stored in low oxygen were tested.

batches of flakes. Cans (samples) from the same batch in several instances had quite different flavors; also much wider differences in carotene contents were observed than could be accounted for by the analytical and sampling methods. These observations, based on several months' analyses, led to the suspicion that some variable in the processing procedure may not have been adequately controlled. Not all the differences in samples could reasonably be attributed to the "nature" of the product.

The suspicion was well founded. Gas analyses for oxygen content were made on randomly selected cans from several batches of flakes. The oxygen in the gas in the tested cans varied from 2 to 20%. On the basis of this observation, samples of all batches of flakes were immediately reexamined and reevaluated for flavor acceptance on the basis of the percentage of oxygen in the gas in the cans. The resulting data indicated that the testing of some of the batches of flakes had been prematurely discontinued. Examination of these data on the relation between oxygen in the container and flavor showed, in many cases, that canned samples in which the oxygen content of the gas was 6%

Table 6.—Sample data illustrating effect of oxygen content of can atmosphere on carotene, ascorbic acid and flavor acceptability of precooked sweetpotato flakes after prolonged storage [1]

Run No.	Processing Code [2]	Oxygen in Container (%)	β-Carotene (p.p.m.)	Ascorbic acid (mg./100 g.)	Flavor acceptability	Storage Period (days)
			At Time of Preparation			
F43-1	A—	—	500	94	Good	0
F43-2	A+	—	503	92	Good	0
			After Storage at 70° F.			
F43-1	A—	14.0	365	78	Off	395
	A—	1.5	349	81	Good	395
	A—	19.1	376	76	Off	395
	A—	12.1	450	82	Off	395
	A—	2.0	418	96	Off	395
F43-2	A+	3.7	509	82	Good	385
	A+	18.2	424	77	Off	385
	A+	17.0	564	77	Off	385
	A+	17.4	417	77	Off	385
	A+	3.8	420	81	Good	385
	A+	5.6	453	81	Good	385
			After Storage at 100° F.			
F43-1	A—	18.0	365	59	Off	451
	A—	18.2	349	59	Off	451
	A—	18.3	376	55	Off	451
	A—	4.0	456	69	Good	451
	A—	4.0	418	69	Sl. Off	451
	A—	8.4	404	64	Off	451
F43-2	A+	15.4	397	60	Good	453
	A+	6.6	414	63	Good	453
	A+	7.9	407	64	Good	453
	A+	7.2	388	63	Good	453
	A+	19.4	361	54	Off	453
	A+	18.8	385	58	Off	453

[1] Goldrush variety.
[2] A = atmospheric cook; — = without Tenox VI; and + = 0.1% Tenox VI (dry basis).

or below had acceptable flavor. Data obtained on reevaluations of all 16 batches of flakes, based on an analysis only from cans containing less than 6 percent oxygen (an arbitrarily selected quantity) are given in Table 5. It will be noted, in comparing data in Table 5 with data in Tables 3 and 4 that the batches of Goldrush flakes processed without antioxidant and where periodic testing had been discontinued earlier were found to have acceptable flavor in containers at the lower oxygen levels. Comparable samples of Unit I Porto Rico flakes were of poor flavor.

Sets of five and six cans were selected later from the different batches of canned flakes in storage and the oxygen content of the gas in each container analyzed. The flakes were then analyzed for carotene, ascorbic acid, and flavor acceptability. Representative data are given in Table 6 for samples of Goldrush flakes which had been processed by atmospheric steam cooking with and without antioxidant, and which had been held in storage at 70° and 100° F. Data in Table 6 substantiate those given in Table 5. The relationship of low oxygen content to the stability of carotene, ascorbic acid, and flavor is more clearly shown in this table. Data from the other sets of comparable samples were similar. These data were omitted because most of the storage periods were shorter.

Materials balances for experimental batches of flakes are given in Table 7. It should be kept in mind in evaluating this data that the accumulation of data on materials balances was not one of the initial objectives of the study. Hence, no effort was made to account for the quantities of puree adhering to equipment or the losses in discarding the first material over the double drums. These losses were considerable in view of the fact that each 225 pounds processed represented nine pureeing and three separate drum drying operations (75 pounds per run—flakes from three runs composited).

DISCUSSION

One of the more practical and significant findings coming out of the 1958-59 season's

Table 7.—Processing—materials balances for experimental batches of flakes

Run No.	Storage (days)	Raw mat. (lbs.)	Peeled weight (lbs.)	Peel & trim loss [1] (%)	Cooked weight (lbs.)	Cooking loss [2] (%)	Total peel, trim, & cooking losses [1] (%)	Weight of flakes (lbs.)	Yield (%)
				Goldrush					
F42-8	50	225	143.0	36.5	—	—	—	20.3	9.0
F42-9	52	225	148.6	34.0	108.4	27.1	51.8	21.4	9.5
F43-1	56	225	145.1	35.5	124.1	14.5	44.8	23.7	10.5
F43-2	58	225	148.6	34.0	123.6	16.8	45.1	23.9	10.6
F44-7	141	225	145.7	35.2	103.4	29.0	54.0	20.1	8.9
F44-8	142	225	153.3	31.9	110.6	27.8	50.8	22.3	9.9
F44-9	147	225	151.2	32.8	126.4	16.4	43.8	24.4	10.8
F45-1	150	225	151.3	32.8	126.6	16.3	43.7	23.3	10.4
				Unit I Porto Rico					
F43-4	5	225	131.4	41.6	112.3	14.5	50.1	28.5	12.7
F43-5	10	225	129.7	42.3	121.3	6.0	46.1	29.8	13.2
F43-6	17	225	130.7	41.9	119.8	8.3	46.8	30.1	13.4
F43-7	20	225	129.5	42.4	103.8	19.8	53.9	24.4	10.8
F45-2	102	150	92.8	38.1	72.1	22.3	51.9	17.9	11.9
F45-3	103	150	95.4	36.4	87.6	8.2	41.6	23.4	15.6
F45-4	108	225	137.7	38.8	111.0	19.4	50.7	27.9	12.4
F45-5	110	150	95.7	36.2	87.2	8.9	41.9	23.4	15.6

[1] Basis weight of raw material.
[2] Basis peeled weight.

work relates to the efficiency of an antioxidant, Tenox VI,[5] in increasing the shelf-life (flavor stability) of the sweetpotato flakes in which it was incorporated. Since Tenox VI contains butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate, and citric acid, little can be said as to the specific action of these ingredients. Any one or all four may have served as the antioxidant(s) delaying the development of the typical "hay-like" odor and flavor which invariably develops in unprotected flakes stored in air. Although BHA, BHT, citric acid, and propyl gallate have been approved by the Food and Drug Administration, U. S. Department of Health, Education and Welfare for use in some food products, their combined use has not been approved for sweetpotato flakes.

The tardy observation that the oxygen content of the atmosphere in the sealed canned samples of flakes varied from 2 to 20%, when it should not have been higher than 2% in any, was nevertheless made in sufficient time to throw some light upon the data being obtained. When oxygen values were available for comparison with the carotene, ascorbic acid, and flavor values of particular samples, the data did not appear to be as erratic as was first supposed. Higher values for carotene and for ascorbic acid and greater flavor stability were obtained for samples with the lower oxygen content in the container atmosphere. At the termination of the experiments most of the samples, however, were good if both the oxygen content was low and an antioxidant had been incorporated in the flakes.

The finding that ascorbic acid content of the flakes diminishes quite constantly with no acceleration relatable to flavor deterioration may indicate that this vitamin is not concerned with the development of off flavors. The roll of carotene, if any, in off flavor development is less clear. More carefully controlled experimental conditions are apparently required, to determine the quantitative relationship between the oxygen in the atmosphere of the canned products, the moisture, the antioxidant, and constituents such as carotene and ascorbic acid.

However, if the product quality is maintained by careful control of each step in the process, the incorporation of an antioxidant, and sealing in tin cans in an atmosphere of nitrogen containing less than 2 percent oxygen a satisfactory product results. Good quality experimental flake products have been produced by two different methods of cooking, from two varieties of sweetpotatoes, and from cured sweetpotatoes which have been held in 60° to 62° F. storage for as long as 102 to 150 days. The products, however, are experimental. More developmental work is needed on them, particularly with respect to finding an acceptable antioxidant and improving stability. This work should be undertaken before they are offered for commercialization.

SUMMARY

Sixteen batches of experimental precooked dehydrated sweetpotato flake products were prepared during the 1958-59 season. Variables involved were as follows: pressure cooking at 240° for 18 minutes, atmospheric steam cooking at 212° for 25 minutes, Goldrush and Unit I Porto Rico variety sweetpotatoes, raw materials processed at two stage intervals after curing, and preparation of flakes with and without antioxidant. Canned nitrogen-gas-packed flakes ranging in moisture content from 3.2 to 5.6% (average 4%) were stored at 70° and 100°.

Good product stability was obtained in the batches of flakes prepared with antioxidant (0.1% Tenox VI[5], dry solids basis), and in the individual samples of these same batches in which the oxygen content of the atmosphere in the sealed container was less than 2%. These two conditions were the major ones determining the stability characteristics of the experimental flake products. When these two conditions were met, carotene, ascorbic acid, and flavor retention were higher than when the conditions were not met.

The investigations demonstrated that good quality flakes could be made by both methods of cooking, from both varieties of sweetpotatoes tested, and from stored sweetpotatoes. They further demonstrated that flakes containing antioxidant and sealed in an atmosphere low in oxygen could be safely stored at 70° and 100° for over a year. Although satisfactory methods of producing experimental products of good quality and stability have been demonstrated, evidence has also been provided showing the need for further developmental work before large scale production can be recommended.

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III. PREFERENCE EVALUATION

Storage studies on the experimental batches of sweetpotato flakes described in Section II of this report were made by the Quartermaster Food and Container Institute for the Armed Forces through procedures that have become standardized during the last 5 years on the basis of experience from similar storage-stability testing of a wide variety of products. In these studies the dependent variable is consumer preference, defined in terms of the level of rating of the product by groups of consumers using the "hedonic scale." The reconstituted product is served as it might normally be eaten, as mashed sweetpotatoes.

The method is designed primarily to establish relative preference among experimental treatments and to determine how preference varies with time in storage. The preference results are broadly predictive of actual acceptance, as defined on the basis of a behavioral criterion, such as the percentage of soldiers who will take a food from the serving line in the mess hall.

The primary objective of the present study was to establish the direction of the effects of the experimental variables on preference. The preference ratings cannot be used to classify samples as "acceptable-unacceptable," since they do not have the necessary precision to permit cut-off points which are valid for the general population. However, the general level of ratings can provide useful information when interpreted by comparison with similar data on a wide variety of food items obtained under the same conditions and with comparable samples of consumers. Although data of the present study will be discussed in this light, such interpretation will not have status comparable to the conclusions based upon relative preference.

The tests at the Institute may be contrasted with those described in Section II. The latter

tests were made by a small panel of technologists who were familiar with the product. They knew what its flavor was originally, had probably developed a rather firm concept of what it should be, and their judgments of "unacceptable" were based on the detection of what they considered an undesirable off-flavor. In contrast, the groups of people who tested at the Institute had no knowledge of the problem, had no particular concepts or biases about the product, and in all probability evaluated the samples simply as a food to eat. In other words, they were typical consumers. It is certain that the consumers and the technologists responded in the same way to many of the same factors, but it is also probable that many of their criteria differed.

MATERIALS AND METHODS

1. *Materials*

Twenty-four cans of each of the experimental treatments as described in Section II, were placed in 40° F. storage until the time of initiation of the studies. Experiment I, on flakes prepared from raw material subjected to a short storage period of 5 to 58 days after curing was begun in December 1958; while Experiment II, on flakes made from roots stored a longer period of 102 to 150 days after curing was begun in March 1959. When testing began the cans of each treatment were randomly divided into two lots, one to be stored at 70° F. and the other at 100° F. At each withdrawal period, two cans of each treatment were used for preference testing.

2. *Preparation*

Samples were prepared as mashed sweetpotatoes by the following recipe:

112 g. Flakes
9 g. Butter
9 g. Sugar
2 g. Salt
360 ml. Boiling water

The boiling water was poured on the other ingredients, and the mixture was stirred constantly for about 3 minutes or until smooth. In Experiment II the same recipe was used for Goldrush, but for the Porto Rico flakes the recipe was changed by reducing the water to 280 ml. This change was made because of the observation during the course of Experiment I that when both varieties were made up by the standard recipe, the Porto Rico preparation was consistently thinner. The amount of water was adjusted for the Porto Rico flakes to give a consistency comparable to that of the Goldrush. This consistency had previously been judged as optimal for preference, although the fact had not been established by actual tests.

Samples were prepared in stainless steel pans and were placed in a hot water bath at 140° F. where they were held while serving. The recipe was made up twice to serve each group of test subjects. The maximum time allowed after preparation until serving was completed was 45 minutes, but the average time required was about 25 minutes.

3. *Test Procedure*

All tests were run in the Institute's Sensory Testing Laboratory which has such features as air conditioning, test booths, and separate areas for preparation and serving. Samples were rated for preference by the hedonic scale method, which uses a 9-point rating scale with verbal anchors expressing successive degrees from "dislike extremely" to "like extremely." (1) [8]

Individual samples were identified by random code numbers. The samples, about one tablespoonful in quantity, were served in small porcelain dishes. The four samples tested at a session were served to each of the 20 subjects in a group, with the order of serving varied among subjects so that each sample was served equally often in each time-order position. A minimum of 30 seconds was allowed between samples during which time the subject either drank or rinsed his mouth with water.

4. *Test Subjects*

Test subjects were drawn from the laboratory's regular pool of about 700 volunteers. It includes military and civilian personnel, both men and women. A random list of these volunteers is prepared by tabulating machine punch cards, and people are called in order (by-passing those who cannot come at the time) until the list is exhausted; then a new listing is prepared.

5. *Test Design*

There were 6 independent variables in this study. This included the 4 processing variables as described in Table 1 of Section II and the

temperature and time of storage of the sweetpotato flakes. The variables are summarized here as follows:

Variety: (a) Goldrush and (b) Unit I Porto Rico (Porto Rico).

Antioxidant: Processed (a) with and (b) without Tenox VI.[5,7]

Cook: Cooked (a) under steam pressure and (b) by atmospheric steam.

Prestorage: Cured roots stored (a) for a short time (5 to 58 days) and (b) for a long time (102 to 150 days) before processing. Both varieties were subjected to short and long prestorage; however the actual times were quite different for the two varieties (see Table 1, Section II).

Temperature: Sweetpotato flakes stored at (a) 100° F. and (b) 70° F.

Time: Refers to the length of time the flakes were in controlled temperature storage. Withdrawals for testing were at 0, 1, 3, 6, and 12 months. The 1-month test could not be run on flakes of Experiment I due to an overload of work in the laboratory.

To reduce the "session" or "group" effects, it is important to select the right variables to be confounded with subject group, i.e., variables whose several levels are not presented to the same group of subjects at the same time.

With two of the variables in the present study, no choice was possible. Since samples from Experiment I and Experiment II were prepared at different times, they could not end their storage periods at the same time; hence, they had to be tested in separate experiments. Samples being withdrawn at the successive time periods could not be tested at the same session. Choice was possible among the other four variables.

With a factorial set of treatments too large for evaluation under homogeneous conditions, it is possible to form several smaller sets such that those treatments within smaller sets are compared with the maximum precision. The cost of this increased precision is that information is sacrificed on certain other comparisons. It is therefore important that the sets be so chosen that the lost precision is on those comparisons judged to be of least importance.

There were 16 samples at each withdrawal and, since each subject could test only four at

Table 1.—Sets of 4 samples served to the 4 different groups of subjects at each withdrawal

Group	Number of subjects	Description of samples			
		Variety [1]	Antioxidant [2]	Cook [3]	Temperature [4]
I	20	GR	No	Press.	70°
		GR	No	Atmos.	100°
		GR	Yes	Press.	100°
		GR	Yes	Atmos.	70°
II	20	PR	No	Press.	100°
		PR	No	Atmos.	70°
		PR	Yes	Press.	70°
		PR	Yes	Atmos.	100°
III	20	PR	No	Press.	70°
		PR	No	Atmos.	100°
		PR	Yes	Press.	100°
		PR	Yes	Atmos.	70°
IV	20	GR	No	Press.	100°
		GR	No	Atmos.	70°
		GR	Yes	Press.	70°
		GR	Yes	Atmos.	100°

[1] Variety: GR = Goldrush; PR = Porto Rico.
[2] Antioxidant: No = Tenox VI not added; Yes = Tenox VI added.
[3] Cook: Press. = Steam pressure; Atmos. = Atmospheric steam.
[4] Temperature: Flakes stored at 70° F. or 100°.

one time, it was necessary to use four groups of subjects. Table I shows how the samples were grouped. Reading across, each line describes a sample in terms of levels of the four treatment variables: V = variety, T = temperature, A = antioxidant, and C = cook. The comparisons confounded with the blocks are the 4-factor interaction, TACV, the 3-factor interaction, TAC, (both of which are probably valueless) and the single factor, variety. Thus, possibly important information is lost on only the single comparison of the main effect of variety. Stated more specifically, the confounding relationship is:

$$I = VG_1 = TACVG_2 = TACG_1G_2$$

where G_1 and G_2 are the two arbitrary components by which the four groups of subjects can be arranged into a 2 x 2 table.

The dependent variable, preference, was quantified in the usual manner by assigning the values 1 to 9 to the points of the hedonic scale, beginning with "dislike extremely." Figures presented in the tables are arithmetic averages of the values assigned to the points checked.

Tables 3 to 7 represent various classifications of the data, i.e. results are given for the different levels of certain variables as averaged over all levels of the remaining variables. This has been done to help clarify the meaning of the analysis of variance wherever it was deemed helpful. The number of judgments on which the averages are based are not shown in the tables, but they can be easily computed from the experimental design, as shown in Table 2. Results are always shown separately for the two prestorage periods of cured roots, being identified as Experiment I (short prestorage) and Experiment II (long prestorage).

Table 2.—Number of responses included in various classifications of the data for Experiments I and II

Classification of responses	Experiment I [1] (short prestorage)	Experiment II [2] (long prestorage)
Total responses [3]	1,280	1,600
One-way classification:		
Involving time	320	320
Excluding time	640	800
Two-way classification:		
Involving time	160	160
Excluding time	320	400
Three-way classification:		
Involving time	80	80
Excluding time	160	200

[1] 4 withdrawals.
[2] 5 withdrawals.
[3] The number of test subjects was always ¼ of the number of responses.

Separate analyses of variance were made on the data from the two experiments. Results are presented in Table 8 which gives degrees of freedom and mean square for each main effect and interaction as listed and indicates the level of significance as .10, 1, or 5%. A blank in the significance level column means that the effect was not significant at the 5% level.

In line with the confounding relationships discussed above, two different error terms were used. Those effects which were confounded with group were tested against subject effect (computed within group and time). These are indicated by footnotes in Table 8. All other effects were tested against the subject-treatment interaction (computed within group and time). It may be noted that the latter interaction is much smaller, which reflects the greater precision with which the unconfounded effects can be assessed.

In the analysis of variance time effects were handled by means of orthogonal polynomials. In experiment I, with only four withdrawals, this gave linear, quadratic, and cubic effects with 1 degree of freedom for each; in Experiment II there was also a quartic effect because of the additional withdrawal. However, no cubic or quartic time effects are shown; instead they are accounted for as "time residual" (near the end of Table 8), which represents the total of all cubic time effects (Experiment I) or cubic and quartic effects (Experiment II). This was done as a matter of convenience in order to reduce the length of the table. In the original analysis none of the main effect components included in these residuals was significant and components of only one two-factor and one three-factor interaction were significant. Since the four-factor interactions usually defy explanation anyway, no usable information has been lost by pooling all the cubic and quartic time effects into a single table entry.

In analyses such as these, the customary 5% level of statistical significance cannot be accorded the same importance as when obtained from a less complex analyses both because of the large number of significance tests and because of the fact that many of them have been made using the same error term in the denom-

inator. This means that the levels of significance as obtained from the standard F tables must be interpreted with more than the usual caution. Therefore, in the discussion of results that follows only those effects which reach the nominal 1% level of significance will be considered as firmly established. Nominal significance between the 1% and the 5% levels will be considered only as indicating trends.

RESULTS

A. Prestorage of Cured Roots

Possible effects on quality of the length of time the sweetpotato roots were stored, after curing and before processing cannot be assessed with the same precision as the other variables. As materials representing the two storage periods of the cured roots were in different experiments, the effect of this variable could not be tested in the analysis. It is still possible, nevertheless, to draw some conclusions. Initial and final average ratings were identical in each of the two experiments (Table 3), and the grand means differed by only 0.1 scale point. Considering the large number of responses on which each mean is based, it may be concluded with confidence that this variable had no important general effect on the quality of the product. The analysis in Table 8 supports this conclusion. Where an important effect appears for one experiment it usually is found for the other. That this is not true in all instances may be due to experimental error, although it also suggests the possibility that the optimal combination of processing treatments depends upon the length of prestorage.

B. Storage Time of Flakes

Length of time in storage has a special significance in a storage study because product stability problems do not appear immediately but develop over a period of time. It is assumed that time in storage will affect foods adversely, and this assumption is nearly always supported by the data. Thus, the interactions of time with the other experimental variables are often of more interest than the main effect. Table 8 shows that the linear main effect of time was highly significant in both experiments. The fact that there was also a significant quadratic effect in Experiment I, but not in Experiment II, reflects slight differences between the short and long prestorage flakes in rate of deterioration. Since the average ratings across all treatments are so close together, this observation probably should not be accorded much importance.

In both experiments the average level dropped from an initial value of 6.6 to 5.8 after 12 months, indicating a marked loss in quality due to storage. Inspection of the averages at the successive withdrawals (Table 3) suggests that most of the quality loss took place in the first three months, because the ratings level off after this point. However, deterioration was not uniform over all treatments, as is shown by the many significant interactions between time and the other variables. These differential rates of deterioration are discussed in the paragraphs below.

C. Variety

The main effect of variety does not appear to be important. Table 3 shows that the aver-

Table 3.—Effect of variety and time in storage on preference for sweetpotato flakes

Time in storage (months)	Experiment I (short prestorage)			Experiment II (long prestorage)		
	Porto Rico	Gold-rush	Average	Porto Rico	Gold-rush	Average
0	6.5	6.6	6.6	6.9	6.4	6.6
1	[1]	[1]	[1]	6.5	6.4	6.4
3	5.8	6.4	6.1	5.6	6.0	5.9
6	5.5	5.8	5.6	5.8	6.0	5.9
12	5.6	5.9	5.8	6.0	5.6	5.8
Average	5.8	6.2	6.0	6.2	6.1	6.1

[1] Not run.

age ratings for Porto Rico and Goldrush were almost identical in Experiment II. In Experiment I they differed by 0.4 scale point, with Goldrush superior; however, the analysis shows significance only at the 5% level, which in the context of the present experiments considered only as a trend. Further, the change in recipe between the first and second experiments should be noted. The reduction in water for the Porto Rico variety was designed to give the product a better consistency. Although preference tests made on the Porto Rico flakes at 6 and 12 months in Experiment I by the new recipe failed to show any marked improvement in the ratings, it is possible that using the non-optimal recipe in Experiment I caused the trend toward higher ratings for the Goldrush flakes.

Although the two varieties are about equal when ratings are averaged across all treatments, it is not true when the data are broken down according to the other variables. The significant interactions with antioxidant and temperature indicate the possibility that the two varieties respond differently. Also there are a number of significant 3-factor interactions. These will be discussed below.

D. Antioxidant

The main effect of the antioxidant was highly significant (0.1% level) in both experiments, with the samples treated with Tenox VI rating higher on the average. The difference amounted to 0.5 to 0.7 scale point in Experiments I and II, respectively (Table 4). As would be expected, the effect of antioxidant depended on time, but the superiority of the Tenox VI samples did not increase progressively. The antioxidant-time interaction is plotted in Figure 1. The quadratic form of the effect,

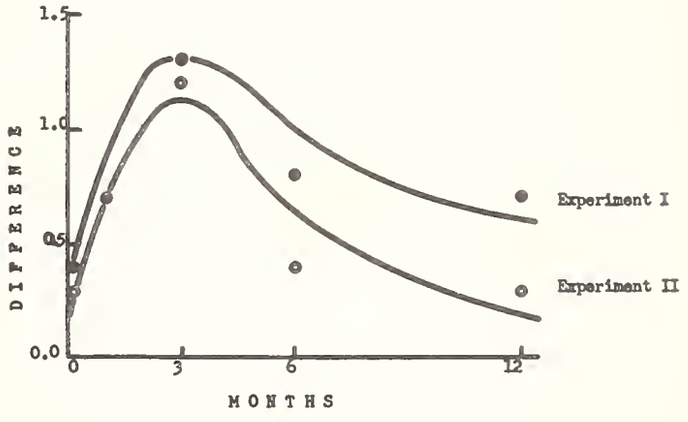

Figure 1. Superiority of preference for antioxidant treated flakes over that for untreated flakes as a function of time.

which is significant at the 1.0% level, is clearly evident. The maximum beneficial effect of the antioxidant occurred at the 3-month withdraw-

Table 4.—Effect of storage temperature, antioxidant, and time in storage on preference for sweetpotato flakes

Time in storage (months)	Experiment I (short prestorage)				Experiment II (long prestorage)			
	100° F.		70° F.		100° F.		70° F.	
	With Antioxidant	Without Antioxidant	With Antioxidant	Without Antioxidant	With Antioxidant	Without Antioxidant	With Antioxidant	Without Antioxidant
0	6.6	6.5	6.8	6.4	6.9	6.7	6.8	6.3
1	[1]	[1]	[1]	[1]	6.8	6.6	6.8	5.6
3	6.8	5.8	6.7	5.2	6.6	6.0	6.4	4.5
6	6.2	5.9	5.4	5.0	6.4	6.2	6.3	4.8
12	6.4	6.3	5.5	5.0	6.5	5.9	5.7	5.0
Average	6.5	6.1	6.1	5.4	6.6	6.3	6.4	5.2
Temperature Average	6.3		5.8		6.4		5.8	
Antioxidant Averages:								
With	6.3				6.5			
Without	5.8				5.8			

[1] Not run.

al; although it was still evident after 12 months, at least in Experiment II.

The degree of the effect of Tenox VI also depended on storage temperature. The antioxidant-temperature interaction is highly significant in Experiment II (0.1% level) and shows a trend in Experiment I. The 70° F. samples were more affected than the 100 F. ones in both cases. Since the relation between these two variables is quite complex, discussion will be postponed until consideration of the temperature variable below.

The effect of Tenox VI also depended on variety. The amount and direction of the effect differed in the two experiments (Table 5). In Experiment I, with short prestorage of the cured roots, the Porto Rico variety was aided more by Tenox VI; but in Experiment II, with long prestorage of the cured roots, the Goldrush variety was aided more. The variety-antioxidant interaction is significant (0.1% level) in both cases. This suggests that the two varieties respond differently to storage, i.e. that something happens to the Goldrush roots during storage to make it more susceptible to the antioxidant effect.

E. Cooking Temperature

The main effect of cook was highly significant (0.1% level) in both experiments, with the atmospheric cook superior both times; however, the amount of the effect was not large in either case. The differences, in terms of the averages across all withdrawals, were only 0.4 and 0.2 scale point for Experiments I and II, respectively (Table 6).

The effect of cooking temperature depended to an important extent on length of time raw mataerials were in storage, with the superiority of the atmospheric processed flakes generally increasing as storage time was extended. The cook-time interaction is highly significant (0.1% level) in both experiments. (Figure 2).

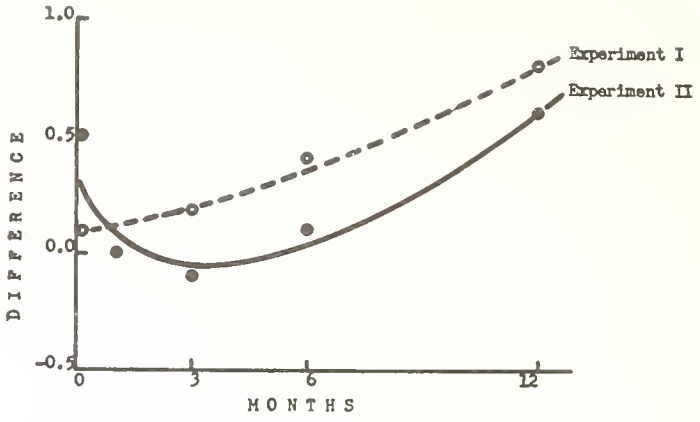

Figure 2.—Superiority of preferences for atmospheric cook flakes over that for pressure cook flakes as a function of time.

In Experiment I the relation is linear. The atmospheric cook started at a low level but fast became superior and increased progressively; while in Experiment II the atmospheric cook was superior only initially and at 12 months, resulting in a quadratic effect. The net conclusion is the same: Either process is suitable for roots processed shortly after curing, but when roots are held for longer periods the atmospheric cook is superior.

The 2-factor interactions of cook with storage temperature, with antioxidant (Table 7) and with variety are not significant for either experiment (Table 6); however, some of the 3-factor interactions are significant for one experiment or both. These were: (a) Variety-temperature-cook interaction in Experiment II only, (b) variety-cook-time interaction in both experiments. Possible interpretations of these interactions are discussed in the following section.

F. Storage Temperature

This variable gave what are perhaps the most interesting and important results. The main effect of storage temperature was highly

Table 5.—Effect of antioxidant and variety on preference for sweetpotato flakes

Variety	Experiment I (short prestorage)			Experiment II (long prestorage)		
	With Antioxidant	Without Antioxidant	Difference	With Antioxidant	Without Antioxidant	Difference
Goldrush	6.3	6.1	0.2	6.6	5.6	1.0
Porto Rico	6.3	5.4	0.9	6.4	5.9	0.5
Average	6.3	5.8	0.5	6.5	5.8	0.7

Table 6.—Effect of cook, variety, and time in storage on preference for sweetpotato flakes

Time in storage (months)	Experiment I (short prestorage)				Experiment II (long prestorage)			
	Porto Rico		Goldrush		Porto Rico		Goldrush	
	Atmos.	Press.	Atmos.	Press.	Atmos.	Press.	Atmos.	Press.
0	6.5	6.5	6.7	6.6	7.0	6.8	6.8	6.1
1	[1]	[1]	[1]	[1]	6.6	6.3	6.3	6.6
3	5.8	5.8	6.7	6.2	5.6	5.7	6.0	6.1
6	5.7	5.3	6.0	5.6	5.8	5.9	6.1	5.8
12	6.4	4.9	6.0	5.9	6.1	5.9	6.1	5.1
Average	6.1	5.6	6.3	6.1	6.2	6.1	6.3	5.9
Cook Averages:								
Atmospheric	6.2				6.2			
Pressure	5.8				6.0			

[1] Not run.

significant (0.1% level) in both experiments, with the flakes stored at 100° F. superior, when ratings are averaged across all withdrawals (Table 4).

The effect of storage temperature depended on time, as would be expected since it is only through time that the differential effects of temperature can develop. The temperature-time interaction is significant for both experiments. Figure 3 is a plot of these interactions, which are both principally linear. It should be noted that, during storage, preference for both the 100° F. samples and the 70° F. samples dropped from their initial values (Table 4).

The effect of storage temperature depended, to some extent, upon variety. The variety-temperature interaction is highly significant (0.1% level) in Experiment I, and shows a trend (5.0% level) in Experiment II. In the first, Goldrush showed a greater margin of superiority for the 100° F. flakes—1.0 scale point as compared to only 0.3 scale point for Porto Rico. The trend in Experiment II was

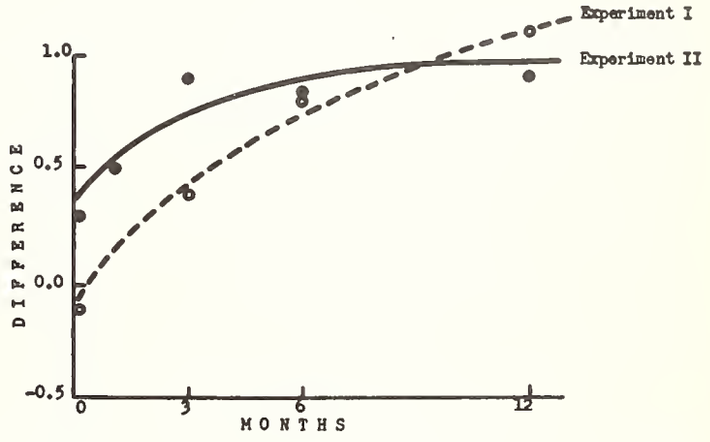

Figure 3. Superiority of preference for flakes stored at 100° F. over that for flakes stored at 70° F. as a function of time.

Table 7.—Effect of cook, antioxidant, and time in storage on preference for sweetpotato flakes

Time in storage (months)	Experiment I (short prestorage)				Experiment II (long prestorage)			
	With Antioxidant		Without Antioxidant		With Antioxidant		Without Antioxidant	
	Atmos.	Press.	Atmos.	Press.	Atmos.	Press.	Atmos.	Press.
0	6.8	6.6	6.4	6.5	7.0	6.8	6.8	6.2
1	[1]	[1]	[1]	[1]	6.8	6.8	6.1	6.1
3	6.7	6.8	5.8	5.2	6.7	6.3	5.0	5.5
6	5.6	6.0	6.0	4.9	6.5	6.2	5.4	5.6
12	6.4	5.4	5.8	5.4	6.5	5.7	5.6	5.2
Average	6.4	6.2	6.0	5.5	6.7	6.4	5.8	5.7

[1] Not run.

contradictory, i. e. the Porto Rico variety showed greater superiority with the 100° samples. The complexity of these relationships in Experiment II is indicated by the significant (0.1% level) variety-temperature-time interaction. For the Porto Rico variety the superiority of the 100° samples increased constantly with time and rose to a high level (1.2 scale points), but for Goldrush the difference between temperatures was smaller and remained fairly constant.

The effect of storage temperature also depended upon the presence or absence of antioxidant. The antioxidant-temperature interaction is highly significant (0.1% level) in Experiment II and shows a trend in Experiment I. The averages in Table 4 show that the samples without Tenox VI developed the greatest difference between temperatures in both experiments; 0.7 vs. 0.4 scale-point in Experiment I, and 1.1 vs. 0.2 scale-point in Experiment II. This relationship was affected by time in Experiment II, where the quadratic component of the antioxidant-temperature-time interaction is significant at the 0.1% level. For the Tenox VI samples there was little difference between temperatures until the last withdrawal at 12 months, whereas there was an important effect for the samples without Tenox VI from 1 month on. In experiment I the samples with and without Tenox VI were affected to about the same extent by temperature throughout storage and, consequently, the interaction is not significant. (Table 8).

Table 8.—Analysis of variance of preference data from 2 storage experiments on precooked dehydrated sweetpotato flakes

Source of variation	Experiment I (short prestorage)			Experiment II (long prestorage)		
	d.f. [1]	Mean square	Significant level, %	d.f. [1]	Mean square	Significant level, %
Variety [2]	1	38.16	5.0	1	2.40	
Antioxidant	1	97.35	.1	1	243.36	0.1
Temperature	1	108.69	.1	1	170.30	.1
Cook	1	40.97	.1	1	16.00	.1
Time						
(linear) [2]	1	105.40	.1	1	181.45	.1
(quadratic) [2]	1	57.00	1.0	1	14.63	
Variety-antioxidant	1	14.38	.1	1	25.50	.1
Variety-temperature	1	23.42	.1	1	8.41	2.5
Variety-cook	1	1.23		1	4.62	
Antioxidant-temperature	1	8.61	5.0	1	68.06	.1
Antioxidant-cook	1	9.28	5.0	1	4.41	
Temperature-cook	1	5.91		1	.20	
Variety-time						
(linear) [2]	1	.04		1	.91	
(quadratic) [2]	1	3.68		1	42.43	2.5
Antioxidant-time						
(linear)	1	3.70		1	4.50	
(quadratic)	1	12.66	1.0	1	23.72	.1
Cook-time						
(linear)	1	20.10	.1	1	1.12	
(quadratic)	1	.05		1	24.90	.1
Temperature-time						
(linear)	1	63.98	.1	1	14.04	1.0
(quadratic)	1	7.50	5.0	1	3.54	
Variety-temp.-cook	1	3.51		1	25.00	.1
Variety-antiox.-temp.	1	.49		1	39.69	.1
Variety-temp.-cook	1	5.91		1	.90	
Antioxidant-temp.-cook- [2]	1	39.55	5.0	1	15.60	

Source of variation	Experiment I (short prestorage)			Experiment II (long prestorage)		
	d.f. [1]	Mean square	Significant level, %	d.f. [1]	Mean square	Significant level, %
Variety-antiox.-time						
(linear)	1	3.66		1	.08	
(quadratic)	1	5.57		1	3.54	
Variety-temp.-time						
(linear)	1	6.78		1	17.40	.1
(quadratic)	1	7.65	5.0	1	1.22	
Variety-cook-time						
(linear)	1	30.30	.1	1	7.60	2.5
(quadratic)	1	8.89	5.0	1	9.84	1.0
Antioxidant-temp.-time						
(linear)	1	.07		1	.00	
(quadratic)	1	.28		1	21.73	.1
Antioxidant-cook-time						
(linear)	1	2.69		1	9.03	1.0
(quadratic)	1	50.53	.1	1	6.60	5.0
Temperature-cook-time						
(linear)	1	.27		1	1.20	
(quadratic)	1	.17		1	.51	
Variety-antiox.-temp.-cook [2]	1	1.73		1	1.96	
Variety-antiox.-temp.-time						
(linear)	1	20.61	.1	1	.15	
(quadratic)	1	4.29		1	3.89	
Variety-antiox.-cook-time						
(linear)	1	2.08		1	6.66	
(quadratic)	1	4.52		1	.23	
Variety-temp.-cook-time						
(linear)	1	.72		1	.15	
(quadratic)	1	2.84		1	20.09	.1
Antioxidant-temp.-cook-time						
(linear) [2]	1	.05		1	21.12	
(quadratic) [2]	1	6.32		1	4.01	
Variety-antiox.-temp.-cook-time						
(linear) [2]	1	.90		1	6.12	
(quadratic) [2]	1	39.09	5.0	1	.32	
Time residual [3]	16	14.13		32	7.18	
Subject (within group and time)	304	6.48		380	7.59	
Subject-treatment (within group and time)	912	1.78		1140	1.3487	
Total	1279			1599		

[1] Degrees of freedom.
[2] Subject (within group and time) used as error term. All others tested against the subject-treatment interaction (within group and time).
[3] Total of all cubic (Expt. I) and all cubic plus quartic (Expt. II) effects of time.

DISCUSSION

The main value of data in a study of this type lies in assessing the relative effects of the experimental variables, since differences between treatments are always more reliably determined than are the actual levels of rating. It is necessary to go beyond the study itself to find a comparison standard for interpreting these levels; however, people who have had considerable experience with such data usually feel that interpretations based on the general level of rating are meaningful. If one keeps in mind the limitations of this approach, particularly the large and unknown error, it is permissible to use it in the present case.

Because of the large number of responses involved, it is safe to assume that the general level of preference for the product has been accurately established. Considering both experiments, 720 consumers in 9 independently selected groups made 2,880 judgments (Table 2). Thus, the overall means are probably representative of what would be expected from a similar population under the same conditions of testing. Evidence previously obtained by the Institute, both from laboratory preference tests and from attitude surveys in the field (2), shows that sweetpotatoes as a product type are not particularly well liked. They tend to rate about average for vegetables, while vegetables, as a class, are the least liked of all broad classes of foods. In the present study the average level of preference, considering both varieties and both experiments, was 6.6 initially, dropping only to 5.8 after 12 months of storage. While there are many vegetables which usually rate higher than this when preparation and quality are optimal, these initial ratings are comparable to the best that have been obtained in this laboratory for sweetpotato dishes. Based on an overall evaluation of the results, these dehydrated flakes may be considered as very good relative to their product type.

Establishing a scale rating below which an item should be considered unacceptable would require determining when the product had deteriorated to the point that a consumer would not buy it; or if he bought it, would not eat it; or if he ate it, would not enjoy it. Obviously, the cutoff point would vary depending on the criterion of behavior chosen. Thus, it is necessary to be arbitrary, as was done with the flavor tests described in Section II, where the time of the first detection of an objectionable off-flavor was considered as the end-point.

Any significant drop in preference rating indicates a probable lowering of acceptance. How large a difference should be considered important? This is sometimes an important consideration where there is a large N, and where differences are so small that they can be intuitively rejected as important determinants of acceptance behavior and yet may still be significant. The answer has to be a studied guess based on experience with many different products. In the present experiment, it is believed that a difference of less than 0.5 scale point should not be accorded much importance. Further, it would be reasonable to set a scale value of 5.5 as an arbitrary end-point. This is 1.1 scale points below the initial preference level, an amount which usually is highly significant in the statistical sense. Any treatment rating at that level would be considered as too poor for the commercial market since many consumers would note that it was deteriorated. This approach provides two standards — a "tight" one at a scale value of 6.0, below which a treatment should be viewed with some suspicion, and an "easy" one at 5.5, below which a treatment is beyond consideration.

Using these criteria, we see that on the average (Table 3) the product is on the borderline of the "tight" standard after only 3 months storage, but does not drop to the lower standard even at 12 months. But the phrase "on the average" is important. Ratings can be averaged in many ways. Table 4, for example, shows that the experiment averages include a lot of bad with the good. Note that most of the 100° F. treatments stayed above the "tight" standard throughout the study, whereas the 70° samples without antioxidant fell below the "easy" standard at the 3-month withdrawal. This again emphasizes that the main value of such an experiment lies in determining the optimal processing and storage conditions. It is an added value that this study is also able to demonstrate with fair assurance that the product was initially of good quality, and that certain treatments retained this quality during a year's storage.

This was a good experiment in that most of the main effects of the variables can be clearly identified, also in that the results can serve as a basis for decisions in further work on the

product. The effect of time in storage was the expected straightforward one of constant loss of quality. The effects of storage temperature, antioxidant, and cook were also consistent, so it is possible to identify one level of each of these variables as better than the other. The effects of the other two variables, variety and length of prestorage of the raw material, were more ambiguous. Main effects of these variables were absent; however, the relationships indicated in the interactions might suggest directions for further investigation.

Cook and antioxidant affected the general quality picture in the same way. The Tenox VI was not uniformly helpful, but was never harmful. Its main influence was on material stored at 70° F., which deteriorated very quickly without the antioxidant, although there is some indication that it also helped with the slower deteriorating 100° samples. Similarly, the atmospheric cook samples were not uniformly superior throughout storage, but the occasional higher ratings for the pressure cook samples which appear in the tables are probably well within the range of experimental error. At the 12-month withdrawal the atmospheric cook seems clearly superior. Thus, even though the overall difference is small, the results indicate the advisability of cooking at atmospheric pressure. It was noted above under "Results" that several of the 3-factor interactions of cook with the other variables are significant. Normally this would be interpreted to mean that the superiority of the atmospheric cook is not general, but is dependent upon having certain particular combinations of precessing elements. For example, the data show that the atmospheric cook was better at 70° F. storage and the pressure cook was better at 100°; however, this was true only for the Porto Rico variety. The trend was the opposite for Goldrush. It is possible that a close interdependence of cook and variety does exist in fact; however, common sense would dictate seeking some other explanation.

The fact that many of the cans of flakes were found to have a high oxygen content in the head space (see Section II) provides a clue. The evaluation reported in Section II showed that these high oxygen samples deteriorated more rapidly than the others. Then we need only assume that the closure failure which resulted in these cans did not occur randomly, but affected certain treatment combinations more often than others, and the interactions are easily explained.

The effect of storage temperature, where the samples stored at 100° F. were consistently better than those stored at 70°, is highly unusual. The difference developed over time, steadily increasing because the 70° samples dropped faster than the 100° samples, although the latter lost quality to some extent also. Results of hundreds of storage studies run at the Quartermaster Food and Container Institute, just as those run elsewhere, have supported the maxim "Higher temperature, poorer stability." Since we can hardly suppose that the law of the acceleration of chemical reaction with increasing temperature was suspended in this case, we must assume that the deteriorative reactions which affected the 70° samples proceeded at an even more rapid rate in the 100° samples. Then we must look for some other reaction which took place, perhaps independently, at the same time—a reaction which changed flavor in such a way as to enhance preference. Further, we may assume that the temperature range between 70° and 100° is somehow critical for this reaction, since it proceeds much faster at the latter temperature. The nature of this change is suggested by the technologists' observation that at the later withdrawals most of the 100° samples appeared darker than the 70° samples and that they had a caramellike or baked taste. This is a flavor which should suit the product, judging from the frequent use with sweetpotatoes of methods of preparation involving browning. It seems likely that the caramellike flavor masked the unpalatable flavor resulting from normal deterioration. An alternate explanation might be that it substituted for flavor initially in the product but lost during storage; however, the fact that the antioxidant also helped in maintaining preference for the 100° samples supports the masking explanation. If the effect of the reaction which was depressed by the antioxidant was merely to remove original flavor and leave the product relatively tasteless, there would be no reason why the Tenox VI should help the 100° samples.

This 100° F. storage effect suggests the possibility of accomplishing the caramelization during the original processing. Then one might expect the product to be better liked initially and because of the masking, maintain acceptability during storage. That this would work is

not a foregone conclusion. We may be dealing with a reaction which depends for its usefulness on its taking place slowly and at the same time as the normal deterioration. Perhaps its value may even depend on its being incomplete at the time the flakes are used. An initially fully caramelized product might be subject to a different type of deterioration. The possibility of inducing a controlled caramelization during processing does deserve investigation.

The main effect of variety showed only a doubtful trend in one of the two experiments and should not be considered important. Similarly, the results of the two experiments show that the length of prestorage of the raw sweetpotatoes after curing had no general effect on preference level. This means that raw materials varying over the whole range included in these experiments should be suitable for processing. However, there were a number of statistically significant interactions of variety with other variables, also some apparently important interrelations between prestorage time and other variables, as shown by comparison of the results of the two experiments. These have been described in the "Results" section. Their main importance lies in the suggestion of various possibilities of obtaining an improved product by adjusting processing methods according to certain characteristics of the raw material. This assumes that the differential results with the different raw materials were related to readily identifiable characteristics such as sugar content and proportion of fiber. It implies a kind of detailed process control which is quite normal in regular production.

It should be noted that the prestorage variable of cured roots was not a "pure" one. The definitions of "short" and "long" were not the same for the two varieties. For Goldrush the "short" period was 38 to 53 days longer than it was for Porto Rico, and the "long" period entailed about the same amount of difference. The presence of this confounding leaves open the possibility that some of the effects attributed to variety may have been the result of differences in prestorage time, and *vice versa*.

Section II discusses the problem of widely varying oxygen content in the head space of the cans, and indicates that the flakes in cans with the higher oxygen were subject to more rapid deterioration. The degree to which this factor may have affected results of the preference tests can be estimated only indirectly, as no gas analyses were made on the Institute samples. Since selection of the cans to be sent to the Institute was random, it is likely that high oxygen content occurred among them just about as frequently as among the can retained at the Southern Utilization Research and Development Division. Another question is whether all treatments were equally likely to have been affected, as would have been the case if closure failure occurred randomly during processing. If it occurred more often with certain treatments than with others, this could not be detected; since the deterioration effect of the high oxygen would appear as part of the treatment effect. Samples received at the Institute were randomly selected at each withdrawal.

When high oxygen occurred even in one of the two cans of a particular treatment at a particular withdrawal, it could have lowered the rating to make it appear "out of line" with the other data. Some out-of-line values were apparent, but they could also have been session effects. The overall result of the appearance of out-of-line values, if they occurred randomly and frequently, would have been to cancel out differences among treatments, since all ratings would have been "loaded" with an irrelevant factor. The fact that many significant differences were found suggests that high oxygen due to random closure failure occurred with low frequency. An alternative explanation would be that off-flavors due to high oxygen were not such as to alter preference to any important extent; this would ,however, seem unlikely, because oxidized flavors are usually unpleasant.

CONCLUSIONS

1. Length of prestorage of the sweetpotato roots after curing had no overall effect on preference; however, the results suggest the possibility that the optimal combination of processing conditions may depend to some extent on the length of prestorage.
2. Variety had little or no effect on average preference, indicating that the Goldrush and Porto Rico varieties are, in general, equally suitable raw materials for manufacturing these flakes; however, there were interactions with other variables, suggesting the possibility that the two varieties may respond differently to prestorage or processing.

3. There was a marked loss in overall average preference over the 12-month period to the point where acceptability would be considered questionable; however, this loss did not occur uniformly. Certain treatment combinations dropped only slightly; others dropped into the definitely unacceptable range, some of them after only 3 months. This demonstrates the possibility of designing a processing method that will give a stable, acceptable product.

4. Flakes stored at 100° F., although they showed a preference loss during storage, were consistently and definitely superior to those stored at 70°. This indicates the occurrence of some reaction with a sharply differential rate in this temperature range (apparently caramelization), and suggests the possibility of redesigning the processing method to obtain the effect initially.

5. On the average, flakes packed with antioxidant (Tenox VI) were more stable than those packed without it. Flakes stored at both temperatures were improved by the antioxidant, but the effect was much more marked in the samples stored at 70° F. The beneficial effect of the antioxidant was most evident after 3 months storage, but it was apparently of some value even after 12 months.

6. Average preference for samples processed by atmospheric steam was slightly but significantly higher than for those processed under pressure. The superiority of the atmospheric cooking process was most evident after 12 months of storage, and for the samples processed with antioxidant. Although the atmospheric cook process was superior only when used in combination with certain levels of other variables, the pressure cook process was not superior in any combination.

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